Staircasing errors due to orthogonal meshing of electromagnetic cavities in FDTD.

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Abstract:

Staircasing of surfaces is a known and well documented source of error in FDTD models on orthogonal structured meshes; however, very little work focuses on such errors in simulations of electromagnetic cavities. This work examines the different errors that arise as a direct result of using an orthogonal approximation of a hollow spherical shell. The spherical shell used has a radius of 1 m and is constructed of a simple material with a conductivity σ = 1000 S/m and a thickness h = 1 mm. This material was represented using a thin boundary SIBC model allowing a mesh size much larger than the thickness of the material. The orthogonally meshed sphere was illuminated using a plane-wave and the electric field measured at the centre allowing the shielding effectiveness (SE) to be calculated.

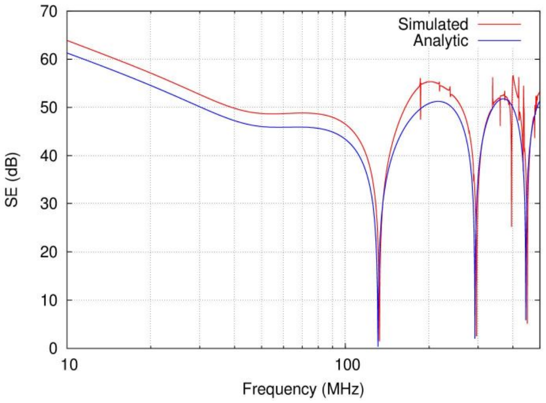
There are some prominent errors in the simulated SE in Figure 1. The resonant frequencies of the cavity are shifted slightly due to the imprecise representation of the geometry. The resonances are consistently at higher frequencies corresponding to a smaller effective radius, this can be attributed to the inner edges of the orthogonal mesh that dominate the resonant behaviour since they are closer to the centre than the actual smooth surface of the unmeshed sphere.

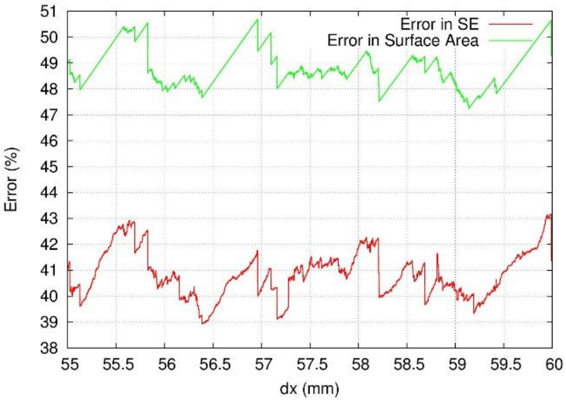
At frequencies above the first resonance there are a number of spurious resonances that are not apparent in the analytical results. These extra resonances are in fact expected spherical resonances that should have a node at the centre of the shell. Due to difficulties in observing exact positions in a Yee cell grid, further exacerbated by the geometric inaccuracies of an orthogonally meshed structure, the observation point at the centre does not lie exactly on the node of these secondary resonances.

The magnitude of SE of the FDTD model is consistently higher than the analytical result. This error can be related to the fact that an orthogonal approximation of a curved surface has a greater surface area than the surface being modelled. In the case of a sphere, this error is around 50%. The simulation was repeated using different mesh sizes (dx). The sphere was meshed separately for each dx. The error in the SE was calculated at 70MHz since this corresponds to a relatively flat region of the SE (Figure 1) and therefore reduces errors caused by any frequency shift. The results shown in Figure 2 show a strong correlation between the error in surface area and the error in SE.

A common alternative to orthogonal meshing is to use a conformal method. There is a large amount of literature surrounding this topic; however, it is important to note that orthogonal meshing has its advantages. Resource consumption of conformal techniques can become very high for advanced structures. Furthermore, the complexity of implementing a conformal technique in an FDTD code and generating meshes that utilise that code can be daunting with a higher risk of generating instabilities than the simpler orthogonal mesh. Ultimately, it becomes a trade-off between accuracy and performance, with neither method being the definitively best solution.

In this presentation we will explore in further detail the errors that arise due to orthogonal meshing of cavities and methods of reducing those errors. We will also make comparisons of results using orthogonal and conformal meshes and discuss the merits of each method.





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